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# Applying an Underwater Photography Technique to Nearshore Benthic Mapping: A Case Study in a Rocky Shore Environment

**J.-Y. Park† J. Y. Choi‡ and E. Y. Jeong†**

†East-Sea Research Institute
Korea Ocean Research & Development Institute
Uljin, 767-813, Korea
jypark@kordi.re.kr
eyjeong@kordi.re.kr

‡Dept. of Oceanography
Kunsan National University
Kunsan, 573-701, Korea
jinyong@kunsan.ac.kr

**ABSTRACT**

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Underwater photography technique was examined to apply digital raster images to nearshore benthic mapping of Dokdo, which is located farthest east from mainland of South Korea. Seabed underwater-photography survey was conducted for three survey lines at the nearshore zone. A total of 315 quasi-orthogonal color JPEG photographs of the seabed were taken sequentially along the survey lines by using an underwater digital camera system. The digital photographs were post-processed for adjusting the color, brightness and geometry of them using digital image processing software. The post-processed sequential photographs of each survey line were stitched as single image mosaics using a photo stitching software. The resulted image mosaics of Lines 1, 2 and D have 2191 x 48482 pixels (~7.5 m x 168 m), 2717 x 43097 pixels (~9.3 m x 148 m) and 4461 x 29720 pixels (~15.2 x 80 m) in image size (image area), respectively. The image mosaics visually show transitional changes and boundaries of geological features thanks to their panoramic areal coverage. Their high image resolution also allows us to easily identify and classify the sedimentary characteristics and sand bedform features as well as certain benthic organisms. As a final process, we added georeference information to the image mosaics to make a 3-D photo surface bathymetry map and put them into a GIS system.

**ADDITIONAL INDEX WORDS:** *Geomorphology, image mosaic, georectification, GIS, Dokdo.*

## INTRODUCTION

Benthic habitat mapping, which is an integration of biological, geological and physical data, is a fundamental step for managing and preserving coastal zones as well as examining unknown coastal environments. Among the integrated data in the benthic map, surficial geologic data of the morphology and sediment type are essential information because there is a strong correlation between the spatial distribution of different marine organisms and particular surficial geologic characteristics and morphologic features, especially, in rocky shore environments (Barrie and Conway, 2008). Rocky nearshore environment usually has more diverse geological and biological characteristics compared to sandy nearshore environment. Its irregular bathymetric feature, however, results in harsh conditions on accessibility for benthic mappings and sampling surveys.

Dokdo is located farthest east from mainland of South Korea (about 216.8 km) and consists of two main volcanic islets with very steep slopes, called as Dongdo (Eastern Island) and Seodo (Western Island), and 89 small volcanic islets (Figure 1). The nearshore zone between two islets is a semi-closed shallow water environment with a range of 0 m to 15 m in water depth. Due do exposed rock basements and volcanic rocks of various sizes on the nearshore bottom, its bathymetric pattern is irregular, especially, close to the shores of two islets (Figure 1-A). Distance between the two islets is variable with a range of 120 m to 200 m with an average water depth of about 5.4 m (Line 1 in Figure 1-B). Water depth at the southern nearshore zone decreases as going to the north (Figure 1-B). Because of its geographical location and high wave energy condition, however, few scientific researches have been conducted to examine the nearshore environment of the islet.

Since 2009, as a scientific research challenge and a part of coastal-zone survey technique development, the Korea Ocean Research & Development Institute (KORDI) has been conducting a multidisciplinary research project for nearshore benthic habitat mapping of Dokdo. As its first survey site, we selected the southern nearshore zone between Dongdo and Seodo and have been conducting geological and biological surveys.

For identification of nearshore geologic feature and morphology of the islet we conducted an underwater photography survey using an underwater digital camera system for acquiring high-resolution seabed images in addition to a nearshore bathymetry survey using a multibeam echo sounder.

In this paper we describe an underwater photography technique used for making panoramic image mosaics of the surveyed nearshore seabed and show preliminary results of georectified image mosaics with bathymetry information.

## METHODS

The underwater photography survey was conducted for three survey lines of the site for two days from January 17th, 2010 to January 18th, 2010. Lines 1 and 2 are 168 m and 148 m in distance crossing from Dongdo to Seodo, respectively and Line D is 80 m in distance along the dockside located at the west side of Dongdo (Figure 1).

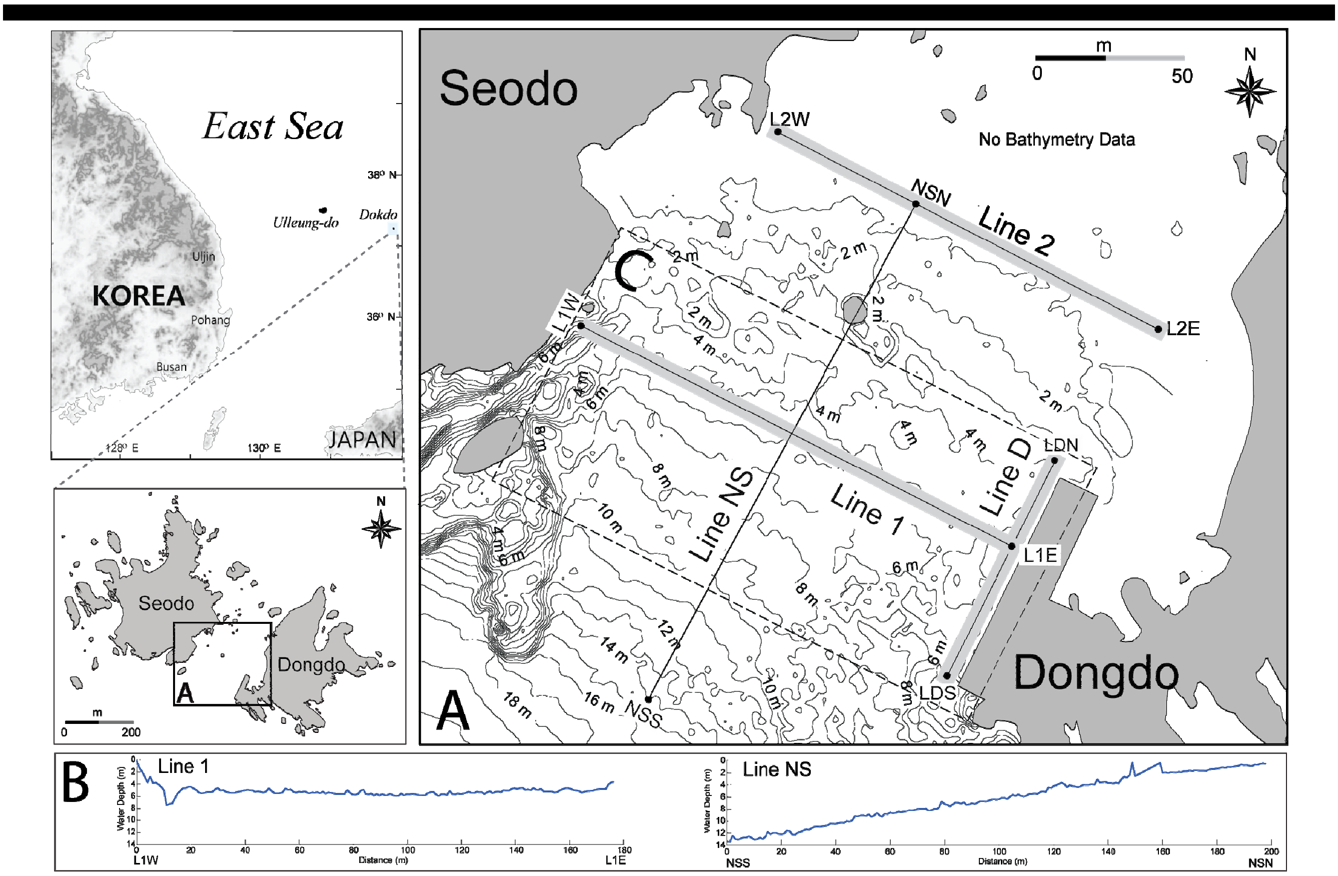


Figure 1. Location Map: (A) Underwater-photography survey lines and bathymetric profile lines; (B) Bathymetric profiles of Lines 1 and NS; (C) Mapping area for 3-D Photo Surface (3DPS) bathymetry map.

Just below the water surface SCUBA divers took quasi-orthogonal color photographs of the seabeds sequentially along the survey lines using an underwater photography system (Step 1 in Figure 2). The camera system consisted of the 12.1-megapixel Nikon D700 DSLR camera, the Nikkor 16-mm wide angle lens and an underwater camera housing. Each photograph was taken by about 30 % overlap in image area with the previous and next ones. For Line 1, especially, we laid a fluorescent yellow rope as a survey guide line on the nearshore bottom surface between Dongdo and Seodo and then took photographs.

A total of 315 color JEPG photographs were taken along the three survey lines. Each digital image has 2784 × 1848 pixels in image size (about 10 m x 7 m in image area for the 5-m water depth zone) and generally about 2.4 MB in file size.

The digital photo images taken from the survey were post-processed in order to get better image quality (Figure 2). The Adobe Photo Shop CS4 software was used to adjust the white balance for color correction and brightness of the images based on the colors of pre-sampled rocks and white objects such as shells in the images (Step 2-1 in Figure 2). As an additional image correction process, we calibrated geometry of the processed images because the original images were optically deformed due to lens distortion of the fisheye lens (Step 2-2 in Figure 2). For the geometry correction we used the PTLens software that corrects barrel distortion of photographs semi-automatically.

After the image correction processing, the post-processed sequential images of each survey line were stitched without sacrificing their original image resolutions as single raster images by using the Echo One DoubleTake software (Step 3 in Figure 2).

In order to add georeference information to the image mosaics, we used the Global Mapper software to georectify them with multiple ground control points (GCP), the geospatial information of which were measured in advance during the field survey. Later, we created three-dimensional georeferenced images by combining the georectified JPEG images with multibeam bathymetric survey data in order to put them into a GIS database system.

## RESULTS

The resulted image mosaics of Lines 1, 2 and D have 2191 x 48482 pixels (~ 7.5 m x 168 m), 2717 x 43097 pixels (~ 9.3 m x 148 m) and 4461 × 29720 pixels (~ 15.2 m x 80 m) in image size (image area), respectively (Figure 3).

Image mosaic of the nearshore zone along the dock also shows a variety of nearshore bottom features (Figure 3-A). Sand ripple features with less than 50 cm in wavelength developing well along the dock are easily indentified from the image. The alignments and flattop shapes of sand ripples indicates that local currents mainly flow bi-directionally in N-S direction along the dock (LD-2A in Figure 3). In addition to the natural features, the panoramic image of Line D also shows in detail the foundation structures of the dock, which are a series of construction pipes with a diameter of about 28 cm.

In the case of Line 1 (Figure 3-B), the sequentially stitched image mosaic shows visually and clearly transitional changes of

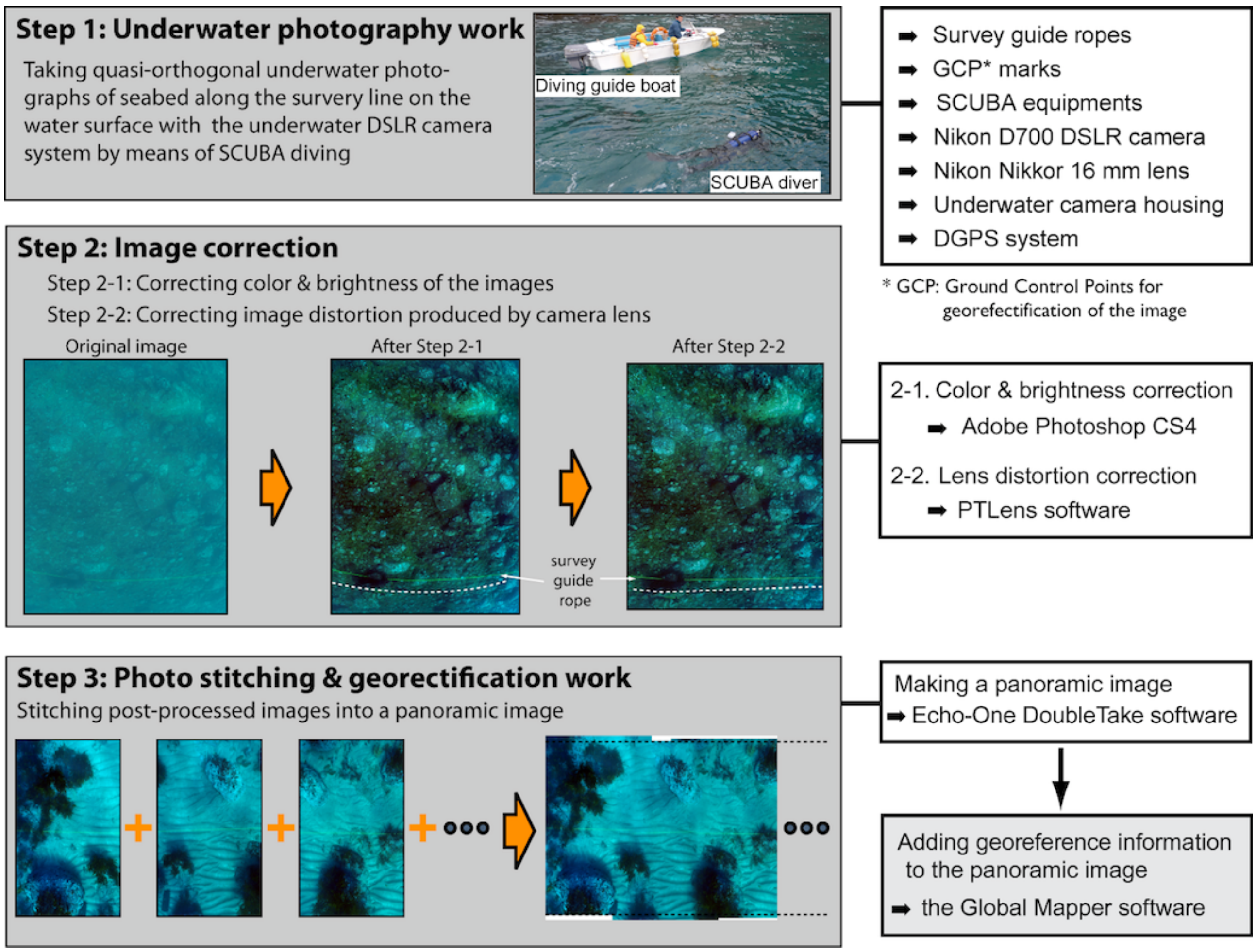


Figure 2. Procedures of the underwater photography work and image data post-processing.

geological features of the seabed in color between Dongdo and Seodo as wells as the boundaries of them thanks to their large areal coverage of several hundred square meters. Most of all, their very high resolutions (higher than 25 square centimeters in resolution) also allows us to easily identify and classify the shapes of rocks and gravels as well as sand bedform features (Figure 3-B). At the nearshore zone of Dongdo sand sediments, which cover the rock basement, are predominant (L1-4 in Figure 3-B), while rocks and gravels of various sizes are dominant in the direction of Seodo (L1-1 - 3 in Figure 3-B).

Image mosaic of Line 2 shows various seaweed patches as well as geological features along the survey line (Figure 3-C). Because the photographs of this survey line were taken without a guiding rope on the bottom, however, the stitched image is not straight but meanders. There also exist several artifacts in the image mosaic produced during the photo-stitching process, which resulted from continuous movements of sea plants according to currents and waves.

In addition to the surficial geologic and morphologic characteristics, other nearshore environmental characteristics can be examined depending on research interest thanks to the high image resolution of the image mosaics (Figure 3).

Figure 4 shows a result after georectifying and coupling the image mosaics of Lines 1 and D with 3D-shaded bathymetry map created from the multibeam bathymetric survey data. As shown in the figure, elongated coverage of the mosaics on the large bathymetry map area does not show realistic effect of real nearshore bottom surface on the final 3D-Photo Surface (3DPS) bathymetry map. When we applied this process for a selective area overlapping each other between the two data sets, however, resulted 3DPS bathymetry map successfully showed 3-dimensional geological and morphological features in detail at the bottom surface (Figure 4-A).

## DISCUSSION

Underwater photography survey was conducted to obtain georeferenced high-resolution rater images for nearshore benthic mapping in the rocky shore environment of Dokdo, South Korea. Resulted image mosaics along the three survey-lines show in detail geological and morphological features of the nearshore bottom surface. When the image mosaics were compared with scanning sonar image data obtained during the same survey period (Kim *et al.*, 2010), the underwater photography technique used in this study is promising for applying to geomorphological survey and benthic habitat mapping especially in the rocky nearshore

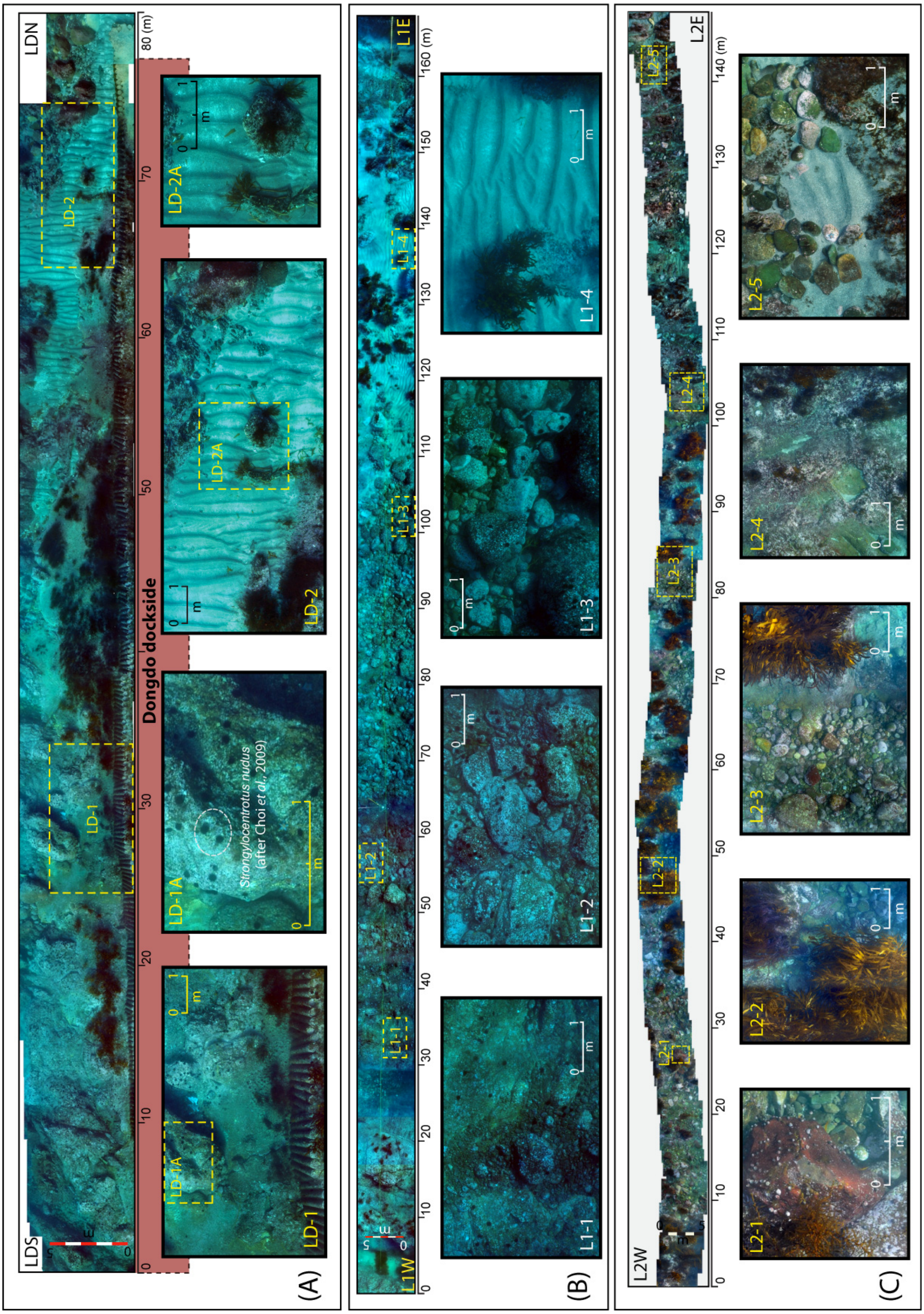


Figure 3. Image mosaics of the three survey lines after post-processing and photo stitching work of the underwater photographs Locations of the survey lines are indicated in Figure 1-A. A veriaty of Spacial geologic and morphologic changes are well reprented in the mosaics. Several benthic organisms are also shown along the survey lines.

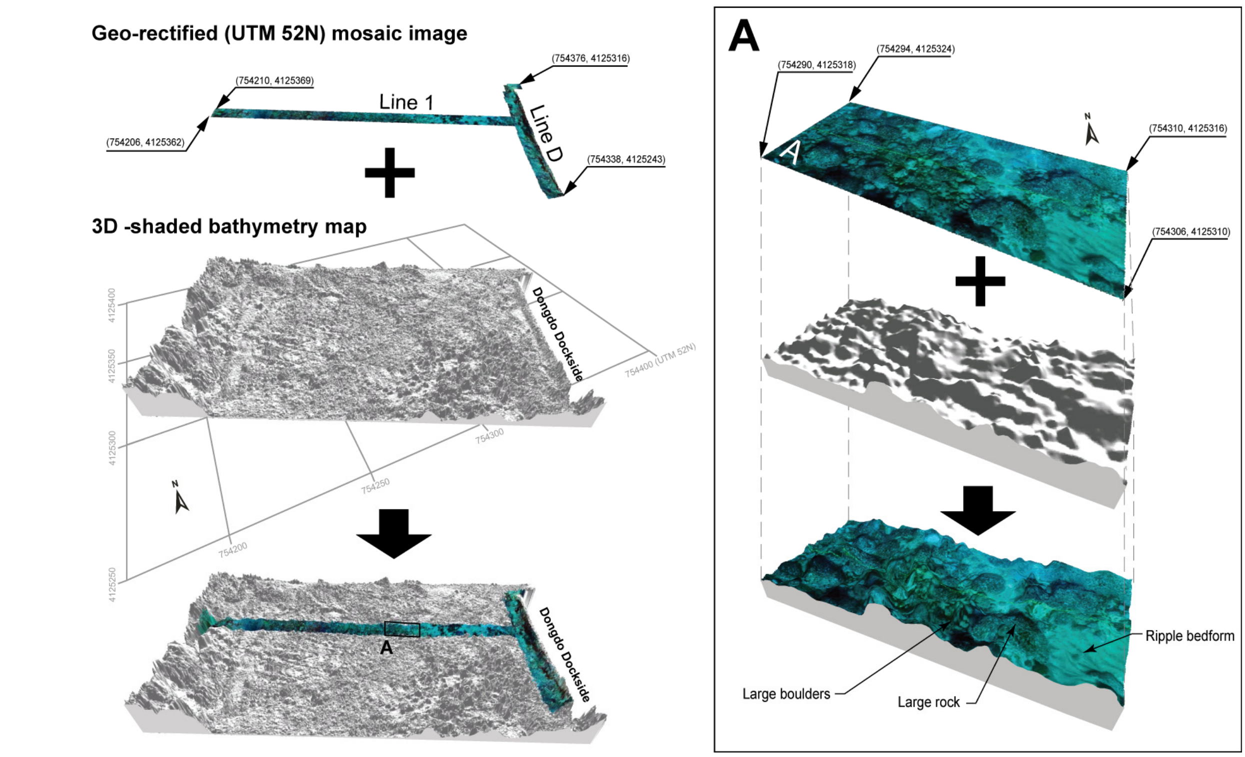


Figure 4. Result of 3DPS bathymetry map after georectifying and coupling the image mosaics with 3D-shaded bathymetry map created from the multibeam bathymetry data: The mapping area is indicated as C in Figure 1-A.; (A) Detailed 3DPS bathymetry map at a selective area overlapping each other between the two data sets.

environment with uneven bottom surface. A similar photomosaic technique using the Adobe Photoshop software already had been tested in a different research filed (Martin[a] and Matin[b], 2002). However, one of important additional steps in our technique might be the georectification process of the image mosaic. A rectified mosaic can be utilized easily by a GIS database system. Most of all, the 3DPS bathymetry map using the georectified image mosaic successfully showed detailed geomorphological features as well as geological features in 3-D.

Despite several technical difficulties (for example, in-situ GCP establishment) in applying the underwater photography technique to the geologic and morphologic mapping, it is expected to be a useful technique for nearshore benthic mapping in sandy beaches as well as in the rocky nearshore environment.

## CONCLUSIONS

This study examined an underwater photography technique including photo stitching and image georectification processes for rocky nearshore benthic mapping. Resulted image mosaics clearly showed spatial patterns of geologic and morphologic features. The georectified image mosaics were very useful for making a 3D photo surface map as well as for benthic mapping. It is expected that this technique may be also applicable to sandy nearshore benthic mapping.

## ACKNOWLEGEMENTS

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